One-Minute Light

Elementary Circuit

by B. Kainka

Loss-free switching, using a Field Effect Transistor (FET) and a capacitor‘s discharge function, is the base theme of this elementary circuit.

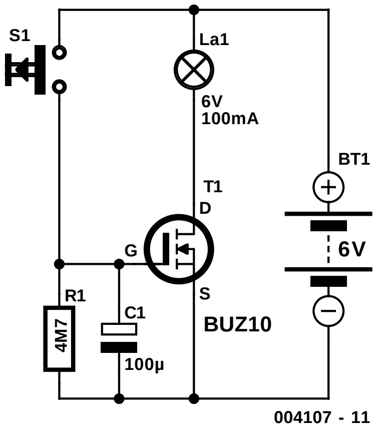

Figure 1. One –minute light circuit diagram — there are just of six components.

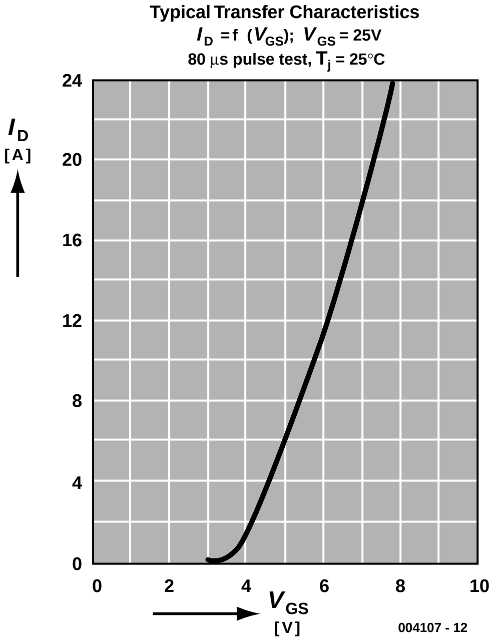

Figure 2. The BUZ10 Field Effect Transistor Transfer characteristics.

The one-minute light circuit shown in **Figure 1** consists of six components, whose functions are easy to point out. The power source is a 6-volt battery, paralleled to the branch point with a lamp and transistor, acting an on/off switch.

Likewise, parallel to the battery is a node linking a pushbutton switch coupled to a very high ohmic valued resistor. The BUZ10 is a Field Effect Transistor (FET), which differentiates itself from a normal transistor, in so much that almost no base current is needed for it to switch on — instead, a voltage at the Gate pin is required. Thus switching without performance loss is possible, which is extremely practical for battery switching circuits.

The voltage potential between the pushbutton switch and resistor determines whether current passes to the lamp through the switching transistor or not.

Standby mode

In standby mode the pushbutton is open. The capacitor is discharged through the resistor. The transistor then blocks, allowing no trickle current to flow to the lamp.

Switch mode

One push on the button instantaneously brings a potential of +6 V to the node. This voltage is also seen at the Gate of the Field Effect Transistor BUZ10. As the Transfer characteristics of this transistor in **Figure 2** shows, when the Gate/Source-Voltage V_{GS} is +6 V, a maximum current of 12 A flows through the Drain-Source junction. Strictly speaking, the diagram is only valid for a Drain-Source-Voltage of 25 V. Actually, such a high current does not flow, due to on the one hand the battery having an relatively high internal resistance and on the other hand the sudden resistance change of the lamp filament from a low ohmic value in its cold state to about 60 Ω in a few milliseconds as the filament glows hot. The current flowing through this branch is easy determined using Ohm’s law.

$$I = U/R = 6\ \text{V} / 60\ \Omega = 100\ \text{mA}$$

By the way, the potential loss across the conducting FET is marginal thanks to the low drain-source resistance of less than 0.1 Ω.

Discharging

Pushing on the button, something else also happens, the capacitor gets a kick-start charge of +6 V. When releasing the pushbutton, this potential remains at the Gate of the BUZ10, due to the fact that the capacitor can only discharge itself very slowly through the high ohmic value resistor. The voltage across the capacitor u_e decreases not linearly, but rather in an exponential fashion:

$$u_c = U{\cdot}e^{-t/RC}$$

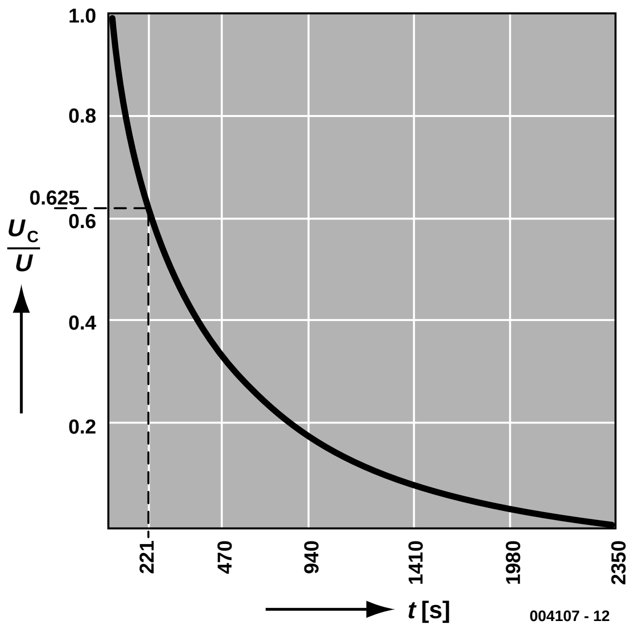

Figure 3. The discharge curve of an ideal capacitor.

Here, U is the initial capacitor potential and e the base of natural logarithms, or 2.718. The corresponding curve (Voltage against Time) is shown in **Figure 3**.

Due to the fact that the capacitor is slowly discharged, and the BUZ10 conducting sufficiently until the Gate voltage drops to about 3.75 V, the lamp glows a short spell after the pushbutton is released.

The afterglow effect can even be determined exactly, that is, mathematically. This involves solving the above formula in the time domain and using an instantaneous voltage of u_c = 3.75 V:

$$\begin{aligned} t &= RC \cdot \ln (u_c/U) \\ &= -(4{,}7 \cdot 10^6 \Omega \cdot 100 \cdot 10^{-6}\ \mathrm{F}) \cdot \ln (3.75\ \mathrm{V}/6\ \mathrm{V}) \\ &= -470\ \mathrm{s} \cdot \ln 0.625 \\ &= -470\ \mathrm{s} \cdot -0.47 \\ &= 221\ \mathrm{s} \end{aligned}$$

This theoretical value will however not be attained due to the fact that capacitors (especially electrolytic ones) also discharge themselves.

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